Comments on:

ENVIRONMENTAL TOBACCO SMOKE:
A GUIDE TO WORKPLACE SMOKING POLICIES

[Draft] EPA 400/6-90/004

Response Addressing:

Chapter 2: Measuring ETS in the Air and Body

Section: Mathematical Models

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SUMMARY: The discussion of mathematical modeling in the EPA draft document, "Environmental Tobacco Smoke: A Guide to Workplace Smoking Policies" (The "Guide") is terse to the point of being devoid of useful content. By ignoring the assumptions, approximations and unknowns inherent in the model-building process, the authors present an excessively optimistic assessment of model applicability. Mathematical models developed to date cannot accurately predict ETS exposure. The authors' conclusions are therefore misleading and require substantial clarification.

COMMENTARY: The EPA draft document, "Environmental Tobacco Smoke: A Guide to Workplace Smoking Policies", contains an unacceptably brief and misleading discussion of mathematical models of Environmental Tobacco Smoke (ETS) and their utility (Chapter 2, page 14). The EPA ignored the several types of ETS models, levels of physico-chemical and mathematical sophistication, and, most importantly, significant limitations of their predictive capability. Some models in the literature are suitable only for very restrictive environments (*e.g.*, environments at thermodynamic, chemical and mechanical equilibrium) [1,2]; others are more generally applicable, but are severely limited by computational requirements [3]. The authors' few substantive statements enumerate selective factors which contribute to exposure estimation, without describing how those factors function within a mathematical framework or indicating their relative significance, and without mentioning the many other, well-documented factors that contribute to exposure estimation. Consequently, it is impossible to evaluate the accuracy of a model or the propriety of a particular model's application on the basis of the information provided in the EPA Guide. The conclusion that

"Mathematical models ... have proved to be a reasonable way to estimate ETS exposure" is, at least, scientifically premature and tendentious.

Mathematical models of ETS represent one type of scientific tool which may be applied to the analysis and prediction of ETS exposure. The EPA Guide does not specify the model (or category of model) useful for this purpose. Blanket endorsement of modeling is unwarranted. The applicability of ETS models is limited both by the required precision of experimental input data and by the sophistication of the mathematical description. Extrapolation of models developed for specialized environments to other situations is especially problematic (and unfortunately, commonplace). The EPA Guide fails to consider these important and inherent limitations of mathematical modeling.

A brief review of relevant mathematical models and their experimental verification illustrate the risks associated with the broad, unfounded generalizations made in the EPA draft.

The most rigorous approach to modeling dispersion of environmental cigarette aerosol involves solution of the fundamental equations of aerosol and fluid dynamics [See, *e.g.*, ref. 4 & 5]. The power of this approach lies in its flexibility. The generalized Navier-Stokes equations complemented by the equations of aerosol evolution are adaptable to an infinite variety of environments and climatic conditions. (Often the aerosol dynamics are subordinate to the equations of fluid flow. That is, macroscopic dispersion is emphasized more than microscopic change.) An example of this approach is the aircraft cabin model of R. H.

Horstman [6]. Recently Kim, Yamamoto and collaborators have also initiated office space studies with simplified models of this type [7]. While the necessary chemistry and physics of a particular environment may be implemented in such a model, the numerical computational demands are often severe. There are relatively few ETS models of this type in the literature.

A second, more common approach involves the simplistic description of ETS spaces as "continuous stirred tank reactors (CSTR)" with varying degrees of embellishment (source and sink terms, mixing factors, etc.). Such "compartmental" models often treat complex physical and chemical processes by grossly empirical approximations [1,2]. Models of this type require extensive, accurate input of environmental parameters (*e.g.*, air flow patterns, mass transport coefficients, component concentrations) both for operation and verification. In addition, the compartmental approach makes the great assumption that spatial dispersion of gas phase and particulate ETS components is instantaneous and uniform, regardless of the geometrical dimensions of the study space. Multi-compartment elaborations of the fundamental CSTR unit improve resolution of the data, but require input of still more empirical parameters. Depending upon the complexity of the environment, such models may be grossly inadequate.

Experimental verification of ETS models is also often difficult. Decisions of sampling method, location and duration must be carefully based upon structural detail of the mathematical description. Exposure estimation is a function of many environmental factors.

For more complex environments (*e.g.*, those involving influx/outflux vents, aerodynamic obstacles, chemical interactions, time-dependent sources and sinks, etc.) highly accurate spatio-temporal resolution of components is required. The Guide omits any discussion of the subtle, but important, interplay between model and experiment in the process of verification. All of these points make reliance on current mathematical models to predict ETS exposure very speculative.

As a final comment, the Guide confuses the term "diffusion", which has a specific mathematical and physical meaning, with the broader generic term "dispersion" throughout the document. In addition, few aerosol scientists would agree with the authors that gas phase ETS is defined as particles smaller than 0.1 micron in diameter (Chapter 1, page 7).

The unacceptably brief discussion of modeling in the Guide implies that mathematical models have been developed which are accurate, reliable predictors of ETS exposure - without qualification. This implication is unsubstantiated and premature. We recommend that this serious shortcoming be addressed by including a full and fair assessment of model types and their limitations.

REFERENCES

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